

Center for Corporate Climate Leadership

Sector Spotlight: Electronics

EPA is seeking to highlight activities to reduce supply chain greenhouse gas (GHG) emissions at the sectoral level. EPA is featuring the electronics sector, specifically flat panel display suppliers' efforts to reduce F-GHG emissions in flat panel manufacturing.

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Overview



Fluorinated greenhouse gases (F-GHGs) are among the most potent and persistent greenhouse gases (GHGs) contributing to global climate change. These gases play a vital role in the manufacture of flat panel displays, namely liquid crystal display (LCD) panels that go into televisions, computer monitors, and many other display products. The overall climate impact of the millions of display products Americans use can be greatly reduced if suppliers of these components take steps to reduce releases of these F-GHGs to the atmosphere.

Over the past few years, brands and retailers such as Wal-Mart, Dell, HP, Lenovo, Best Buy and Acer have taken important steps to encourage further F-GHG reductions among their LCD suppliers by asking suppliers to develop a standard method for measuring F-GHG emissions, set new voluntary F-GHG emissions reduction goals with public timelines for demonstrating progress, and develop annual progress reports.



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What are F-GHGs and How are They Used in Panel Manufacturing?

Fluorinated GHGs such as certain perfluorocarbons (e.g., CF₄, C₂F₆, C₄F₈), trifluoromethane (CHF₃), nitrogen trifluoride (NF₃), and sulfur hexafluoride (SF₆) are among the most potent greenhouse gases (GHGs), with some persisting in the atmosphere for thousands of years, effectively causing irreversible impacts on the earth's climate system. These gases have extremely high global warming potentials, or GWPs, which is a metric used to quantify the impact that a gas has on the climate; a higher GWP means a higher impact.

F-GHGs are commonly used in many types of electronics manufacturing, including the manufacture of flat panel displays, semiconductors, micro-electro-mechanical systems, light emitting diodes, and photovoltaic cells.

Flat panel displays are made up of a series of layers. Layers underneath the screen on the front of a flat panel display have grids of millions of tiny transistors created by depositing and etching materials (e.g., glass, films made up of various metals and chemicals). These layers are produced in manufacturing areas called deposition tool chambers. Flat panel display manufacturers—namely those that produce the panels used in products such as televisions, computer monitors, tablets, and mobile phones—use various F-GHGs during panel production. These gases, which are highly effective in their performance, are used in several panel production processes, including:

- **Etching:** F-GHGs react with glass and materials to etch intricate patterns and create the grid of transistors.
- **Cleaning:** F-GHGs are used to rapidly clean areas of manufacturing tools (chemical vapor deposition, or CVD, tools) where flat panels are etched.
- **Cooling:** Fluorinated heat transfer fluids, which contain F-GHGs, are used in the manufacture of flat panel displays to cool manufacturing equipment.

See Table 1 for some of the process chemicals used by the industry and the environmental impact of the gases if released to the atmosphere.

Table 1. F-GHG Applications and Climate Impact in Flat Panel Manufacturing

F-GHG Compound	Application			Atmospheric Lifetime (years)	Global Warming Potential (100 year)
	Etching	Cleaning	Cooling		
CO ₂	N/A	N/A		variable	1
C ₂ F ₆	✓	✓		10,000	12,200
CF ₄	✓			50,000	7,390
SF ₆	✓	✓	✓	3,200	22,800
NF ₃	✓	✓		740	17,200

Other Gases Used in FPD Manufacturing

F-GHGs are not the only greenhouse gases used in panel production. For example, N₂O, which has an atmospheric lifetime of 114 years and a 100-year global warming potential of 298, is used during deposition to place materials (e.g., glass, metals, chemicals) onto glass. Stakeholders are currently learning more about the impacts of N₂O and other gases in panel production.

Table 1. F-GHG Applications and Climate Impact in Flat Panel Manufacturing

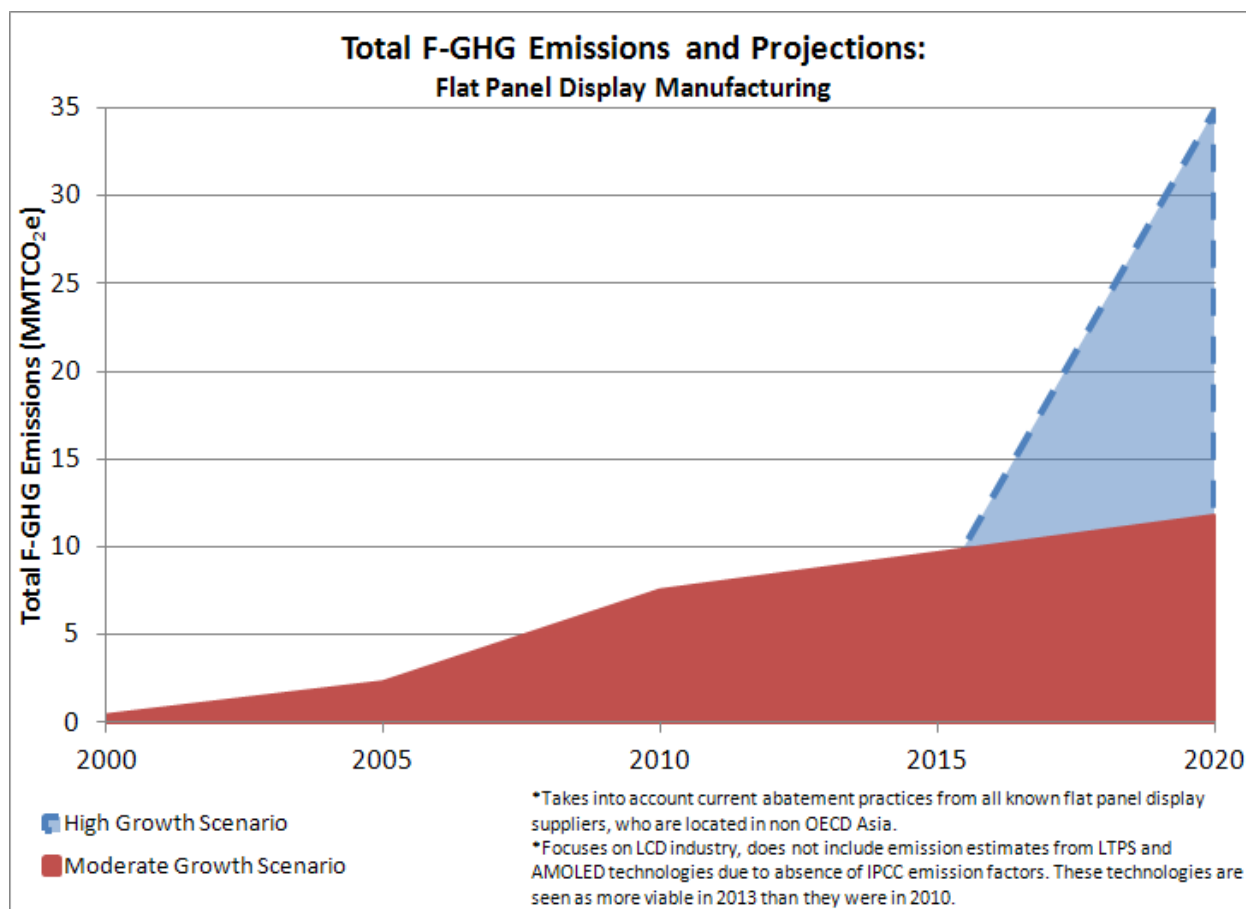
F-GHG Compound	Application			Atmospheric Lifetime (years)	Global Warming Potential (100 year)
	Etching	Cleaning	Cooling		
CHF ₃	√		√	270	14,800
C ₃ F ₈		√		2,600	8,830
c-C ₄ F ₈	√	√		3,200	10,300
Source: IPCC, 2007 <small>EXIT</small>					

During manufacturing of flat panel displays, a portion of F-GHGs pass through the manufacturing tools unreacted and are released into the atmosphere.^[1] A portion of the F-GHGs used in processes may also react in chambers to form by-product emissions of other F-GHGs. In addition, F-GHGs can be emitted from equipment cooling processes through evaporation.

The magnitude of emissions can vary depending on a number of factors including: the specific gas used, the type and brand of equipment used, company-specific process parameters, and the number of F-GHG-using steps in a production process. Companies' manufacturing processes and, consequently, emissions also vary across flat panel manufacturing fabrication facilities, also called “fabs”.

Figure 1 shows total F-GHG emissions from flat panel display manufacturing since 2000, with projections of future emissions under both moderate growth and high growth scenarios.

Figure 1. F-GHG Emissions from Flat Panel Display Manufacturing, Including Projections under Moderate Growth and High Growth Scenarios



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How can F-GHGs be Reduced?

Over the last decade, electronics manufacturers have made significant progress in identifying effective technological solutions to reduce F-GHG emissions. The following approaches to reducing F-GHG emissions resulting from flat panel manufacturing are in use today or are currently being explored:

1. **Abatement via gas destruction technologies:** Both *point-of-use abatement*, where the abatement system is attached to tools, and *centralized abatement systems*, where gases are sent to, and destroyed in, a centralized system, are being used by major panel suppliers. The majority of abatement systems in use are combustion-based. Though suppliers employ a mix of strategies to reduce F-GHGs, abatement remains one of the most effective ways to reduce the majority of F-GHG emissions. To estimate annual emissions and reductions, suppliers can estimate or measure the efficiency of an installed abatement system to destroy or remove gases such as F-GHGs—known as the destruction or removal efficiency (DRE). Most suppliers today use default factors from the 2006 IPCC Guidelines to account for the DRE of abatement systems. However, suppliers may also directly measure DREs using measurement guidelines or protocols.

2. **Alternative chemicals:** Manufacturers can use alternative lower GWP or more efficient gases to accomplish the same result. For example, in the case of CVD chamber cleaning, many manufacturers have modified their processes to be able to use NF_3 instead of SF_6 . Though NF_3 still has a very high GWP, it is lower than that of SF_6 . SF_6 is also less efficient than NF_3 , resulting in more SF_6 emitted per unit of SF_6 used as compared to the use of NF_3 .
3. **Process optimization/source reduction:** Manufacturers can optimize their processes to use F-GHGs more efficiently, especially in the CVD chamber cleaning process, resulting in smaller amounts of gas that are unreacted and emitted.
4. **Other options such as capture and beneficial reuse:** Manufacturers can capture F-GHGs and process them to remove impurities and refine them for reuse. Some suppliers are evaluating the opportunities for reuse. As of now, reuse and recycling has not been implemented widely due to limitations on the effectiveness and cost of available technologies.

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What is the Industry Doing to Reduce F-GHGs?

Over the last decade, major flat panel suppliers have taken voluntary steps to reduce their F-GHG emissions. For example, in 2001, the World Display Industry Cooperation Committee (WDICC)—including the LCD industry associations in Korea, Taiwan, and Japan—agreed to voluntary reduction activities and set a goal to reduce F-GHG emissions to 0.82 MMTCE by 2010. They estimated that these reductions represented one tenth of their anticipated emissions, effectively reducing 2000 baseline levels by approximately 90 percent. ^[2] ^[3]

To meet the reduction goal, many suppliers in participating countries implemented strategies to address their emissions including installing abatement technologies on production lines in their newer generation fabs, namely those built within the last decade. As a result, F-GHG emissions were reduced by 10.1 MMTCE, to where aggregate emissions totaled 1.75 MMTCE. Though these reductions demonstrated significant accomplishments, the WDICC fell short of its goal due to a rise in emissions resulting from a rapid increase in production for LCD panels that were integrated into products such as televisions faster than initially anticipated. ^[3]

Since the WDICC set its initial goals, newer suppliers with growing market share have also emerged and information on their F-GHG emissions reductions efforts is currently unknown. In addition, it appears that some key suppliers are still in varying stages of implementing comprehensive F-GHG emission reductions efforts across their fabs. As worldwide demand for flat panels, namely LCDs, continue to increase, F-GHG emissions are also projected to rise. To mitigate those emissions, it is important that reduction efforts across all major panel suppliers are implemented.

In late 2015, LCD suppliers who were members of the World Display Industry Cooperation Committee (WDICC) committed to a new goal of reducing F-GHG emissions intensity by 30% by 2020. EPA commends LCD suppliers for taking this important step to further reduce F-GHG emissions. Also, beginning in late 2015, the IEEE 1680.1 standard denoting improved environmental performance for computers and monitors, which also underpins the Electronic Product Environmental Assessment Tool (EPEAT) used in institutional procurement, began its revision. One of the criteria stakeholders are examining at the time of this writing would reward reducing F-GHGs from LCD manufacturing.

What Are Individual Suppliers Doing to Reduce F-GHG Emissions?

The Supplier Profiles below detail the efforts of large-area flat panel suppliers to reduce their F-GHG emissions in manufacturing across key areas. The profiles cover mitigation measures and goals, the extent of reduction efforts (whether they include all processes and gases used), the extent to which abatement technologies are installed on newer fabs that manufacture large area panels, and public disclosure efforts.

Most Current Supplier Profiles; Updates feature 2016 information

- [Supplier Profiles for FY2016, includes Summary](#)

Previous Supplier Profiles; Features 2011, 2012, 2013, 2014, and 2015 information, respectively

- [Supplier Profiles for FY2015, includes Summary](#)
- [Summary of Supplier Profiles for FY2014](#)
- [Supplier Profiles FY2014](#)
- [Summary of Supplier Profiles for FY2013](#)
- [Supplier Profiles for FY2013](#)
- [Summary of Supplier Profiles for FY2012](#)
- [Supplier Profiles for FY2012](#)
- [Summary of Supplier Profiles for FY2011](#)
- [Supplier Profiles for FY2011](#)

In the News!

- [Major Companies Push LCD Suppliers to Make F-GHG Reductions.](#) [EXIT](#) July 30, 2014
- [EPA Initiative Aims to Cut Suppliers' F-GHG Emissions.](#) [EXIT](#) September 20, 2013

How can Brands, Retailers, and Large Buyers Contribute to F-GHG Reduction Efforts?

Product assemblers and retailers can play an important role in reducing the climate impacts of the products they sell by sourcing from suppliers with a demonstrated commitment to reducing F-GHG emissions.

For example, over the past few years, brands and retailers Walmart, Dell, HP, Lenovo, Best Buy, and Acer took an important public step to foster further voluntary F-GHG reductions among their LCD suppliers. These companies asked their LCD suppliers to develop a standard method for measuring and recording F-GHG emissions for the industry, establish a voluntary long-term F-GHG emissions reduction

goal with public timelines for demonstrating progress, and develop an annual progress report that can be shared with them and/or other supporting organizations. Since then, other brands have followed suit by engaging their LCD suppliers to better understand their F-GHG emissions and efforts to reduce them.

It is important to note that currently it is difficult and unadvisable to try to compare panel suppliers' F-GHG emissions due to a lack of consistency in estimating emissions, estimating emissions reductions, and monitoring the efficacy of installed abatement systems. Therefore, panel purchasers can use the following set of questions as a starting point to help understand how their panel suppliers are reducing their F-GHG emissions and identify opportunities for discussions to target and implement further mitigation efforts.

[Questions for Suppliers \(PDF\)](#)

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EPA Efforts to Support F-GHG Emission Reductions for Electronics

For more than twenty years, EPA has worked collaboratively with the high-tech electronics industry to identify strategies for reducing greenhouse gas emissions resulting from its operations and from the products it creates for consumers.

- **From 1996 to 2010, EPA's Perfluorinated Carbon (PFC) Reduction/Climate Partnership for the Semiconductor Industry supported and helped facilitate the industry's voluntary efforts to reduce emissions of F-GHGs.** In 1999, Partners voluntarily committed to reducing F-GHG emissions by at least 10 percent below a 1995 baseline. To this end, EPA worked with the industry to identify, evaluate, and implement new technologies to mitigate F-GHG emissions. As a result, industry Partners reduced emissions by more than 50 percent below the 1995 baseline, or by a little more than 2 million metric tons of CO₂e. This reduction is equivalent to the energy used in approximately 103,000 homes per year.
- **From 2002-2010, EPA worked with various companies in the electronics sector to help them inventory their corporate-wide GHG emissions and set and achieve aggressive emissions reduction goals through identifying best practices.** EPA continues to engage companies throughout the electronics industry on promoting the use of renewable energy through its Green Power Partnership, where companies such as Intel, Dell, Best Buy, and Microsoft rank among the top 50 leading Green Power Partners within the United States for their green power procurement.
- **In 2010, EPA published their "Protocol for Measuring Destruction or Removal Efficiency (DRE) of Fluorinated Greenhouse Gas Abatement Equipment in Electronics Manufacturing" (EPA's DRE Protocol).** EPA's DRE Protocol is internationally peer-reviewed and provides a reliable method for measuring the DRE of point-of-use abatement systems for F-GHGs used during the manufacture of electronics.
- **Since 2011, EPA has been working with brands, retailers and other stakeholders** to improve understanding of F-GHG emissions in LCD manufacturing and to help foster criteria in purchasing standards that recognize leadership among panel suppliers reducing F-GHG emissions.

Additional Resources

- [1] IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change.
- [2] Nishida, et al. *PFC Emission Reduction Strategy for the LCD Industry*. Journal of the SID 13/10/2015
- [3] [WLICC Working Group 1 Activity Report on the 2012 FCs Reduction. World LCD Industry Cooperation Committee. November 10, 2011, Tokyo \(PDF\)](#) (2 pp, 47K) [Exit](#)
- EICC: [Assessing and Reducing F-GHGs in the Electronics Supply Chain \(March 2016\)](#) [EXIT](#) (PDF, 7 pp, 1000K)
- EPA: [PFC Reduction / Climate Partnership for the Semiconductor Industry](#)
- JEITA: [WLICC WG1 Activity Report on the 2010 FCs Emissions Reduction](#) [EXIT](#) (PDF, 2 pp, 48K)